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EFFECT OF AIR COOLED BLAST FURNACE SLAG AND POLYPROPYLENE FIBRE ON MECHANICAL PROPERTIES OF CONCRETE

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ABSTRACT

In India, annual production of pig iron is 70-80 million tons and Air Cooled Blast Furnace Slag (ACBFS) production is 21-24 million tonnes. This has created a new challenge for industry for disposal of ACBFS. In order to solve this problem, innovations are required so that we can use ACBFS in construction industry. Further, in India, natural sources for aggregates are very lacking, it is necessary that new aggregates should be sought. The property of blast furnace slag is similar to natural aggregates, the price is cheap and the output is large. Therefore it could be regarded as the substitute of the natural aggregates. The combined effect of ACBFS as replacement for coarse aggregates and fly ash as a partial replacement of cement along with polypropylene as additive on the compressive and flexural strength of concrete has been investigated. Eighteen mixes were prepared at different replacement levels of ACBFS (0% to 100% @20% increment) with coarse aggregate and fly ash was at 10% constant in all mixes. The polypropylene fiber was used with dosage varying of 0.25% - 0.75%@0.25 increment. The compressive strength of concrete and flexural strength was tested after 3, 7 and 28 days of curing. Results indicate that the compressive and flexural strength are in phase with each other. The replacement of ACBFS with coarse aggregates up to 40% increases the compressive and flexural strength of concrete and at 60% marginal decrease in both parameters. On further replacement up to 80% and 100% strength severely reduces the compressive and flexural strength of concrete mix. It is highly recommended that up to 40% of ACBFS can be used as coarse aggregate in concrete along with addition of 0.50% polypropylene.

KEYWORDS: Air Cooled Blast Furnace Slag (ACBFS), Compressive Strength, Flexural Strength, Fly Ash, Polypropylene Fiber

INTRODUCTION

Next to water, concrete is the second most consumed substance on earth. On average, each person uses nearly three tonnes of concrete annually. Portland cement, the major component of concrete is used to bind the materials that make up concrete. The concrete industry produces about 12 billion tonnes of concrete a year. In addition, the cement industry is second only to power generation in the production of carbon dioxide .The contribution of ordinary Portland cement (OPC) production worldwide to greenhouse gas emissions is estimated to be approximately 1.35 billion tons annually (Djwantoro *et al* 2004) Each primary constituent of concrete, to a different extent, has an environmental impact and gives rise to different sustainability issues (Aggarwal *et al* 2010). For dealing with environmental impacts of concrete industry, some replacement has to be worked out which may replace main components of concrete (cement & aggregates) with some waste material of mankind. One such replacement for aggregates is the use of air cooled blast furnace slag. The

use of such waste material will not only decrease the dependency on natural resources but also gives the solution of disposal of industry waste in right way. Blast furnace slag is produced as the by-product in the process of pig iron production in a blast furnace at a rate of about 300 kg per ton of pig iron. Blast furnace slag is tapped from the furnace as a liquid which contains gases held in solution. The conditions of cooling control both the growth of mineral crystals and quantity and size of gas bubbles that can escape before being trapped by solidification of the slag mass. Thus, within the limits imposed by the particular chemical composition, the cooling conditions determine the crystalline structure, density and porosity of slag. Air cooled blast furnace slag has properties similar to natural aggregates and it would not cause any harm if incorporated into concrete (Hiraskar and Patilh 2013). When ACBFS is used, less natural material needs to be mined, transported, and processed. This means less disruption to the land, less energy consumed, less pollution, greenhouse gases generated from mining and transporting natural aggregate (Morian *et al* 2012)

Fly ash, a waste generated by thermal power plants is substitution for cement in concrete production. Fly ash is the best known and one of the most commonly used pozzolans in the world. A pozzolan is a siliceous material which when mixed with lime and water forms a cementations compound. Fly ash is the notorious waste product known for its ill effects on agricultural land, surface and sub-surface water pollution, soil and air pollution and diseases to mankind. Researchers have proposed few ways of reusing fly ash for variety of application. One of the most common reuse of fly ash is in cement concrete. The low-lime fly ash is the prime variety generated in India, although significantly smaller volumes of high-lime fly ash are available in the country (Chatterjee 2011). The utilization of by products as the partial replacement of cement has important economical, environmental and technical benefits such as the reduced amount of waste materials, cleaner environment, reduced energy requirement, durable service performance during service life and cost effective structures. The ordinary Portland cement when replaced with 5 to 50% fly ash, it was observed that 10 % fly ash showed the highest compressive strength at all ages (Hussein *et al* 2013).

Concrete has better resistance in compression while steel has more resistance in tension. Conventional concrete has limited ductility, low impact, abrasion resistance and little resistance to cracking. A good concrete must possess high strength and low permeability. Hence, alternative composite materials are gaining popularity because of ductility and strain hardening. To improve the post cracking behavior, short discontinuous and discrete fibres are added to the plain concrete. These fibres are manufactured using conventional melt spinning. Polyproppylene fibres are thermo plastics produced from propylene gas. Propylene gas is obtained from the petroleum by products or cracking of natural gas feed stocks. Propylene polymerizes to form long polymer chain under high temperature and pressure. However, polypropylene fibres with controlled configuration of molecules can be made only using special catalysts. The raw material of polypropylene is derived from monomeic C_3H_6 which is purely a hydrocarbon. The ductility of fibre reinforced concrete depends on the ability of the fibre reinforced concrete to bridge cruces at high levels of strain. The mechanical properties of concrete increases at 0.40% polypropylene fibre with 10% fly ash content (Saravanan and Palani 2014). The present study encourages the utilization of waste material such as ACBFS and fly ash in concrete along with polyproppylene fibres.

MATERIAL USED

CEMENT

Ordinary Portland Cement (OPC) of grade 43 from a single lot was used in the study. It was fresh and free from any lumps. Cement was carefully stored to prevent deterioration in its properties due to contact with the moisture. Cement conforming to specifications given in IS: 8112 was used as given in Table 1.

Table 1: Properties of OPC 43 Grade Cement

Sr. No.	Characteristics	Value Obtained Experimentally	Values Specified by IS: 8112-1989
1.	Specific Gravity	3.15	-
2.	Standard consistency	31%	-
3.	Initial Setting time	132 minutes	30 minutes (minimum)
4.	Final Setting time	260 minutes	600 minutes (maximum)
5.	Compressive Strength 3 days 7 days 28 days	25.15 N/mm^2 34.68 N/mm^2 46.48 N/mm^2	23 N/mm^2 33 N/mm^2 43 N/mm^2

FINE AGGREGATES

Fine aggregates were collected from Chakki River (Pathankot). It was coarse sand, brown in color. Specific gravity of fine aggregates was experimentally determined as 2.64. Fine aggregates confirming to grading zone II as per IS-383 were used as shown in Table 2.

Table 2: Sieve Analysis of Fine Aggregates

Is- Sieve Designation	Weight Retained on Sieve (G)	%Age Weight Retained on Sieve	Cumulative %Age Weight Retained on Sieve	%Age Passing	%Age Passing for Grading Zone-Ii As Per Is: 383-1970
10 mm	Nil	Nil	Nil	100	100
4.75 mm	17	17	3.4	96.6	90-100
2.36 mm	52	69	13.8	86.2	75-100
1.18 mm	150	219	43.8	56.2	55-90
600 micron	61	280	56.0	44.0	35-55
300 micron	109	2389	77.8	22.2	8-30
150 micron	101	490	98.0	2.0	0-10

COARSE AGGREGATES

The coarse aggregates used were a mixture of two locally available crushed stone of 10 mm and 20 mm size in 50:50 proportions. The aggregates were washed to remove dirt, dust and then dried to surface dry condition. The aggregates were grey in color, angular in shape and having specific gravity was 2.60. Coarse aggregates confirming to IS: 383 were used .The sieve results are presented in table no. 3.

Table 3: Sieve Analysis of Proportioned of Coarse Aggregates

Is- Sieve Designation	50:50 Proportion (10 Mm: 20mm) Weight Retained	Cumulative Weight Retained (G)	Cumulative %Age Weight Retained	% Age Passing	Is: 383-1970 Requirements
80 mm	Nil	Nil	Nil	100	100
40 mm	Nil	Nil	Nil	100	100
20 mm	Nil	Nil	Nil	100	95-100
10 mm	1325	1325	66.25	33.75	26-55
4.75 mm	600	1925	96.25	3.75	0-10

ACBFS

The industrial coarse aggregate used in this study is the waste (air-cooled blast furnace slag) supplied from Vardhman Steel Industry, Ludhiana. The slag was crushed and screened. The maximum size was 20 mm . The chemical and physical properties of the industrial slag are summarized in Tables (4) and (5) respectively.

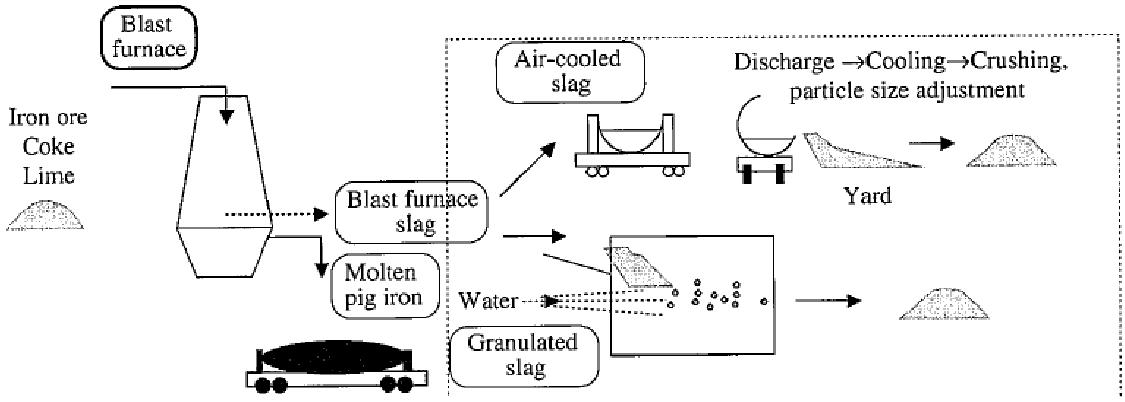

Figure 1: Flow Diagram of ACBFS Production in Iron Plant

Table 4: Chemical Composition of ACBFS

Component	Percentage
Major Components	**95**
Lime (CaO)	30 – 40
Silica (SiO_2)	28 – 42
Alumina (Al_2O_3)	5 – 22
Magnesia (MgO)	5 – 15
Minor components	5
Sulpur (CaS, other sulphides, sulpates)	1 – 2
Iron (FeO, Fe_2O_3)	0.3 – 1.7
Manganese (MnO)	0.2 – 1

(Source: Vardhman Steel Industries, Ludhiana)

Table 5: Physical Properties of ACBFS

Properties	ACBFS
Particle Shape and Texture	Angular and roughly cubical with rough to glassy texture
Specific Gravity	2.0 – 2.5
Absorption Capacity	1 – 8 percent
Angle of Friction	40– 45 degrees
Loss of Mass by Abrasion and Impact	35 – 45 percent
California Bearing Ratio	> 100

(Source: Vardhman Steel Industries, Ludhiana)

FLY ASH

Fly ash is a by-product from burning ground coal in electric power generating plants. Fly ash obtained from Guru Nanak Dev Thermal Plant (Bathinda) was used in study. The chemical and physical properties of fly ash are given in Table 6 and Table 7 respectively

Table 6: Chemical Properties of Fly ash

Sr. No.	Chemical Component	Values	Requirements As Per IS: 3812
1.	$(SiO_2) + (Al_2O_3) + (Fe_2O_3)$ in percent by mass	91.02	Min 70
2.	Silicon dioxide (SiO_2) in percent by mass	86.72	Min 35
3.	Reactive silica in percent by mass	24.80	Min 20
4.	Magnesium oxide (MgO) in percent by mass	0.84	Max 5
5.	Sulphur trioxide (SO_3) in percent by mass	0.59	Max 3
6.	Sodium oxide (Na_2O) in percent by mass	0.50	Max 1.5
7.	Loss on ignition in percent by mass	2.3	Max 5

(Source: The Guru Nanak Dev Thermal Plant, Bathinda)

Table 7: Physical Properties of Fly ash

Sr. No.	Physical Properties	Values	Requirements As Per IS: 3812
1.	Specific gravity	2.22	_
2.	Fineness Blaine' Specific surface in m^2/kg	369.7	Min 320
3.	Lime reactivity — Average compressive strength in N/mm^2	3.4	Min 4.5
4.	Particles retained on 45 micron IS sieve (wet sieving) in%	31	Max 34
5.	Soundness by autoclave test — Expansion of specimen in%	0.23	Max 0.8

(Source: The Guru Nanak Dev Thermal Plant, Bathinda)

POLYPROPYLENE FIBRES

Polypropylene fibres obtained from FORTA CORPORATION (Brand name: ECONO-NET was used in this study. Its properties are given in Table 8.

Table 8: Properties of Polypropylene Fibres

1.	Material	Virgin homopolymer polypropylene
2.	Colour	White
3.	Specific gravity	0.91
4.	Length	38 mm
5.	Acid /alkali resistance	Excellent

(Source: FORTA CORPORATION)

LABORATORY TESTING PROGRAM

MIX DESIGN AND SAMPLE PREPARATION

In this work, one control mix R1 was designed as per IS: 10262. Then 17 mixes were prepared other than control mix at different replacement levels of ACBFS (0 to 100% @increment of 20%) and Polypropylene fiber (0.25% to 0.75%% @ increment of 0.25. Fly ash was kept constant 10% replacement level of cement in every mix. The water/cement (w/c) ratio in all the mixes was kept at 0.50. Water content in each mix was 186 L/m^3. Mix proportions of concrete mixes are shown in Table 9.The compressive strength was determined using cube moulds of size 150 mm X150 mm X 150 mm. The cubes were casted and tested after 3, 7 and 28 days of curing. To determine the flexural strength (modulus of rupture) for each mix, three (150 mm X 150 mm X 700 mm) prisms were casted and tested after 3, 7 and 28-days of curing.The flexural strength test was conducted in accordance with IS: 516 using a simple beam with third point loading at a loading rate of 0.2 kN/s.

Table 9: Mix Proportions of Different Concrete Mixes

Mix	W/C Ratio	Fly Ash (Kg/M^3)	ACBFS (Kg/M^3)	Fibre (Kg/M^3)	Cement (Kg/M^3)	Fine Aggregates (Kg/M^3)	Coarse Aggregates (Kg/M^3)	Water (L/M^3)
R1	0.5	37.20	0	2.275	334.80	717	1165	186
R2	0.5	37.20	233	2.275	334.80	717	932	186
R3	0.5	37.20	466	2.275	334.80	717	699	186
R4	0.5	37.20	699	2.275	334.80	717	466	186
R5	0.5	37.20	932	2.275	334.80	717	233	186
R6	0.5	37.20	1165	2.275	334.80	717	0	186
R7	0.5	37.20	0	4.55	334.80	717	1165	186
R8	0.5	37.20	233	4.55	334.80	717	932	186
R9	0.5	37.20	466	4.55	334.80	717	699	186
R10	0.5	37.20	699	4.55	334.80	717	466	186
R11	0.5	37.20	932	4.55	334.80	717	233	186
R12	0.5	37.20	1165	4.55	334.80	717	0	186
R13	0.5	37.20	0	6.825	334.80	717	1165	186
R14	0.5	37.20	233	6.825	334.80	717	932	186
R15	0.5	37.20	466	6.825	334.80	717	699	186
R16	0.5	37.20	699	6.825	334.80	717	466	186
R17	0.5	37.20	932	6.825	334.80	717	233	186
R18	0.5	37.20	1165	6.825	334.80	717	0	186

RESULTS AND DISCUSSIONS

Compressive Strength of Concrete

The compressive strength of all the mixes was determined at the ages of 3, 7 and 28 days for the various replacement levels of ACBFS with coarse aggregates along with addition of fibers in different proportions. The values of average compressive strength for different replacement levels of ACBFS with coarse aggregates (0%, 20%,40%,60%,80%,100%) and fibre (0.25%,0. 5%, 0.75%) at the end of different curing periods (3 day, 7 days & 28 days) are given in Table 10. These values are plotted in Figure 2 to 4, which show the variation of compressive strength with different percentages of ACBFS and fibre.

Table 10: Test Results for Compressive Strength of Concrete

Mixes	ACBFS (%)	Fibres (%)	3 Days MPa	7 Days MPa	28 Days MPa
R1	0	0.25	8.31	18.35	27.70
R2	20		10.92	20.97	30.10
R3	40		11.67	22.88	32.50
R4	60		12.42	20.81	31.00
R5	80		8.42	17.09	26.00
R6	100		8.19	15.09	24.40
R7	0	0.5	8.67	19.09	28.50
R8	20		9.97	20.58	30.50
R9	40		11.09	22.25	33.20
R10	60		10.68	21.80	32.10
R11	80		8.73	17.82	26.20
R12	100		7.96	17.28	25.30
R13	0	0.75	6.64	13.39	20.50
R14	20		6.27	12.88	19.20
R15	40		6.08	12.32	18.87
R16	60		5.96	11.98	18.07
R17	80		4.87	11.51	17.20
R18	100		3.89	10.05	14.80

It can be observed that the compressive strength of concrete increases up to certain limit and then decreases for all curing ages. The trend is same with 0.25% and 0.5% fiber but different for 0.75% fiber. For 0.25% fiber, the compressive strength values for 0%, 20%, 40%, 60%, 80% and 100% replacement with coarse aggregates was 27.7, 30.1, 32.5, 31, 26 and 24.4 respectively. For 0.5% fiber, the compressive strength values for 0%, 20%, 40%, 60%, 80% and 100% replacement with coarse aggregates was 28.5, 30.5, 33.2, 32.1, 26.2 and 25.3 respectively. For 0.75% fiber, the compressive strength values for 0%, 20%, 40%, 60%, 80% and 100% replacement with coarse aggregates was 20.5, 19.2, 18.87, 18.07, 17.2 and 14.8 respectively. It can be seen that reduction in compressive strength is minor up to 60% beyond which there is noticeable reduction in compressive strength for both 0.25 % fiber and 0.5% fiber. Further with 0.75% fiber case, the concrete failed abruptly even with 0% ACBFS.

The absorption capacity of ACBFS is on higher scale as compared to natural aggregates, thereby absorbing the water available in concrete. This high absorption property disturbs the water-cement ratio resulting in low compressive value. Moreover, the concrete prepared with 0.75% fiber exhibited total compressive failure due to non availability of contact area between cementatious paste and aggregates. Therefore, the combination of (40% ACBFS +0.5% fiber) is recommended as the maximum replacement of coarse aggregates.

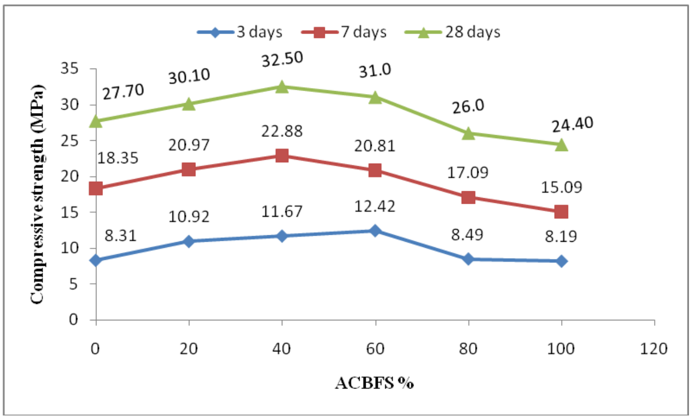

Figure 2: Compressive Strength of Concrete with 0.25% Addition of PPF at Different Curing Ages

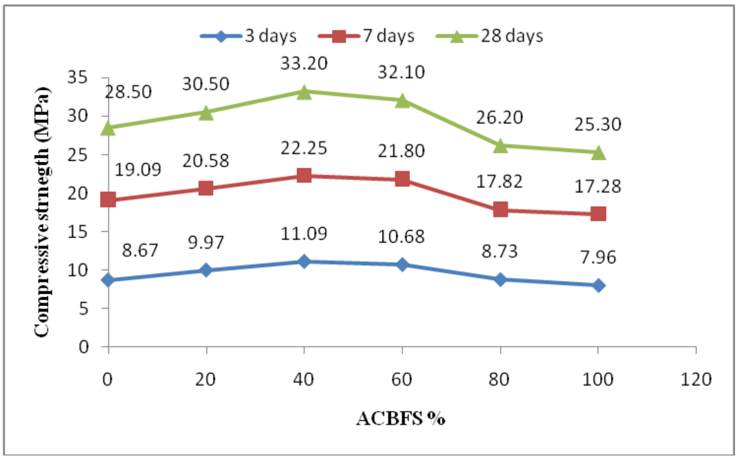

Figure 3: Compressive Strength of Concrete with 0.5% Addition of PPF at Different Curing Ages

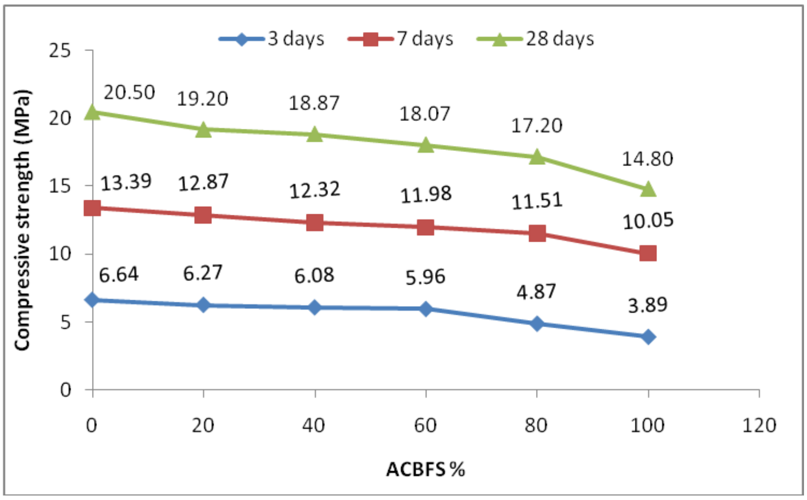

Figure 4: Compressive Strength of Concrete with 0.75% Addition of PPF at Different Curing Ages

FLEXURAL STRENGTH OF CONCRETE

Flexural strength of concrete was determined using three point loading system after 3, 7 and 28days of curing. The flexural strength of the specimen was determined in accordance with IS: 516. The values of average flexural strength for different replacement levels of ACBFS (0 to 100% @ increment of 20%) and polypropylene fiber(0.25 to 0.75% @ increment of 0.25%) at the end of different curing periods (3,7 & 28 days) are given in Table 11. These values are plotted in Figure 5 to 7.

Table 11: Test Results for Flexural Strength of Concrete

Mixes	ACBFS (%)	Fibres (%)	3 Days MPa	7 Days MPa	28 Days MPa
R1	0	0.25	1.63	2.80	4.08
R2	20		1.79	2.83	4.17
R3	40		1.67	3.04	4.42
R4	60		1.53	2.94	4.18
R5	80		1.38	2.42	3.50
R6	100		1.25	2.19	3.38
R7	0	0.5	1.75	3.13	4.61
R8	20		1.82	3.2	4.78
R9	40		1.8	3.45	5.00

R10	60		1.63	2.89	4.62
R11	80		1.56	2.79	3.88
R12	100		1.39	2.43	3.64
R13	0		1.29	2.59	3.78
R14	20		1.12	2.24	3.26
R15	40	0.75	1.03	2.06	3.01
R16	60		1	1.95	2.84
R17	80		0.8	1.54	2.27
R18	100		0.74	1.41	2.08

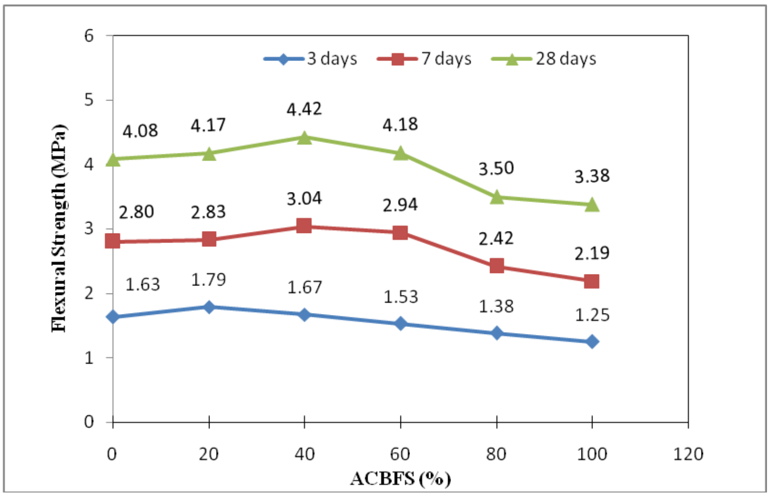

Figure 5: Flexural Strength of Concrete with 0.25% Addition of PPF at Different Curing Ages

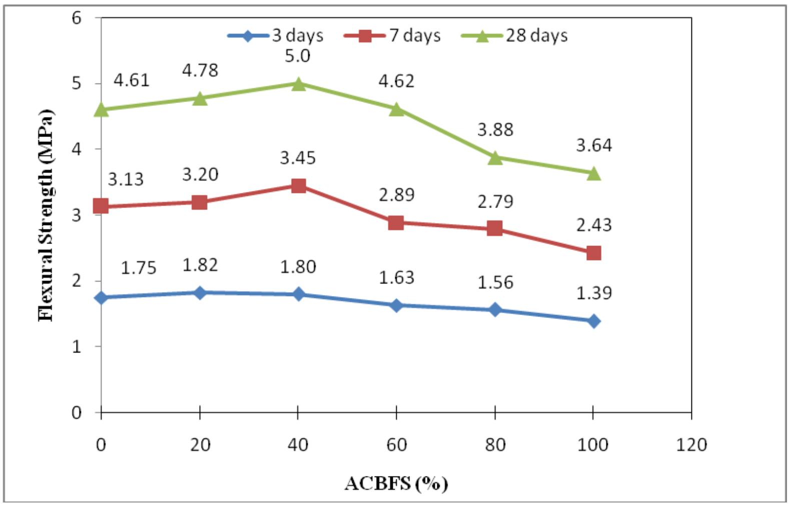

Figure 6: Flexural Strength of Concrete with 0.5% Addition of PPF at Different Curing Ages

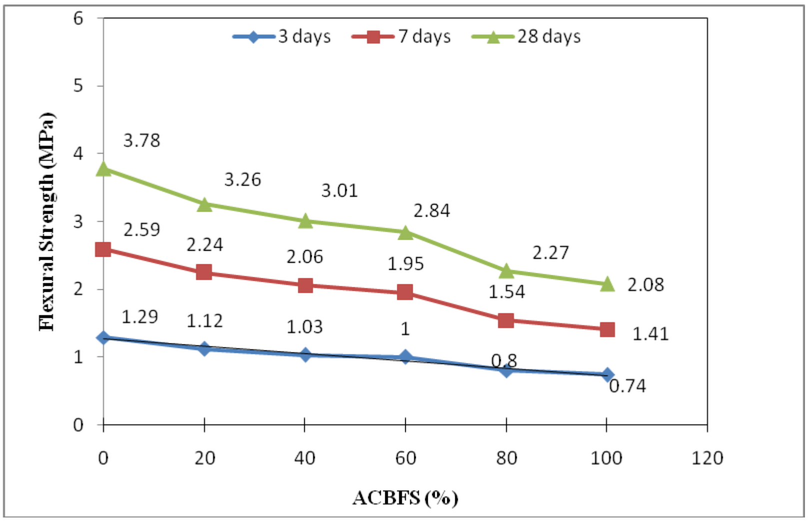

Figure 7: Flexural Strength of Concrete with 0.75% Addition of PPF at Different Curing Ages

CONCLUSIONS

The experimental test highlights ACBFS as a good substitute for coarse aggregates and whatever deficiencies that may result can be easily overcome by use of polypropylene fibres. The compressive and flexural strength of concrete showed improved results. Based on these test results it is now possible to find out enhancements in strengths for different ACBFS and fibres percentages by weight. From test values, the ideal choice would be 40%ACBFS +0.5% fiber+10%fly ash. The increase in compressive strength by using above stated combination is nearly 17% when tested at 28 days. Even at 3 and 7 days testing results are supportive. Similar enhancement in flexural strength is observed, making this combination an efficient material over concrete with the use of local materials and technology.

REFERENCES

1. Aggarwal V, Gupta S M and Sachdeva S N (2010) Concrete durability through high volume fly ash concrete (hvfc) a literature review. Int J Eng Sci Technol**2**(9) :4473-77.

2. Chatterjee A K (2011) Indian Fly Ashes, Their Characteristics, and Potential for Mechano-Chemical Activation for Enhanced Usability.J Mater Civil Eng **23**(6):783-88.

3. Djwantoro H, Steenie E W, Dody M J S and Rangan B V (2004) On the Development of Fly Ash-Based Geopolymer Concrete. ACI Mater J**101** (6): 467-72.

4. Hiraskar K G and Patilh C (2013) Use of blast furnace slag aggregate in concrete. Int J Sci Eng Res **4**:95-98.

5. Hussein A A E, Shafiq N and Nuruddin M F (2013) A Comprehensive Experimental Study on the Performance of Fly Ash concrete. Int J Eng Adv Technol **2**(6):135-42.

6. IS: 10262-1982 (Reaffirmed 2004): Recommended guidelines for concrete mix design, Bureau of Indian Standard, New Delhi-2004.

7. IS: 3812 (Part I)-2003: Pulverized Fuel Ash – Specification, Bureau of Indian Standard, New Delhi-1963.

8. IS: 383-1970 (Reaffirmed 1997): Specification for Coarse and Fine Aggregates from Natural Sources for Concrete, Bureau of Indian Standard, New Delhi-1997.

9. IS: 516-1959 (Reaffirmed 2004): Methods of tests for strength of concrete, Bureau of Indian Standard, New Delhi 2004.

10. IS: 8112-1989 (Reaffirmed 2005): Specification for 43 grade Ordinary Portland Cement, Bureau of Indian Standard, New Delhi-2005.

11. Morian D A, Van Dam T J and Perera R (2012) Use of Air-Cooled Blast Furnace Slag as Coarse Aggregate in Concrete Pavements. Report no FHWA-HIF-12-008. Federal Highway Administration, Washington, DC.

12. Saravanan J and Palani B (2014) Strength properties of polypropylene fibre reinforced fly ash concrete. Int J Recent Sci Res**5** (12): 2218-21.